Dynamic of forest landscape in Heilongjiang Province for one century

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Abstract: With the help of GIS tool of ARC/INFO, ARCVIEW and FRAGSTATS, the map of forest resource distribution of Heilongjiang Province was analyzed in 1896, 1949 and 1981. Using total area, mean patch size, patch density, coefficient of patch size variation, mean patch fractal dimension and mean shape index, we studied the change of forest landscape pattern and the change of each patch types in this region. As a result, the total area of forest landscape and mean patch size decreased sharply, the quantity and density of patchesrincreased, the juxtaposition of patches weakened, the shape of patch tended to become regular, and the border of patch simplified. All these showed that the forest landscape of this area tended to fragment gradually, and the fragment of Korean pine forest is the severest. The diversity of whole forest landscape and the evenness of landscape types distribution reduced gradually. Human impact, instead of climate change and forest community succession, is the most important reason for such dramatic changes.

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Introduction

Landscape is composed of interaction patches according to some rules. The spatial arrangement of patches of different shape and size is called landscape pattern (Wang *et al.* 1997), which is the embodiment of landscape heterogeneity and the result of diversified ecological process in different scale (Fu 1995). Analysis of landscape spatial pattern is one of the centers of landscape study. The change of landscape pattern is the result of interaction between nature, biology and social elements (Turner & Lynn 1988). Patch's shape, size, amount and special combination will influence ecology process and edge effect such as the distribution of different species, creatural movement, stem flow and erode (Wang 2000). Therefore, analysis on landscape pattern change is helpful in discussing the interrelation between landscape pattern and ecology process. Parameters of influencing landscape pattern are patch size, patch shape, patch density and distribution of patches etc. (Gustafson & Parker 1992; Hamazaki 1992). Landscape fragment is an important aspect of landscape pattern change (Bu 1999; Turner 1987), isoline's protract is a new approach to analyze landscape fragment and influence of human activities from a new point of view. In the landscape pattern analysis, we should not only consider patch shape, size and type, but also consider the juxtaposition and evens between landscape patches in landscape spatial pattern analysis (Liu & Chen, 2000), due to the characteristic of landscape's heterogeneity and complexity of patches combination. Therefore Olsen et al. developed a sort of analysis method called modified fractal based on landscape pattern fractal analysis, which is used to describe the diversity of landscape spatial pattern (Chang & Wu 1998).

Landscape change not only influenced natural environment that people depend on, but also regime, economic system, culture and even ideology (Fu *et al.* 2001; David & Michael 2002). Today nearly all landscapes have kept humankind activities brand, to some extent, people control the direction of landscape change. But, the most important thing for us is to find, understand and use general principle of landscape change through short life process, to protect natural environment more effectively, to keep ecology balance, to keep a positive, healthy sustainable developing way (Zang *et al.* 2000). While, driving factors of landscape change also include natural factors, especially climate change, geological vicissitude and great natural phenomenon.

Heilongjiang Province is one of the provinces with the most abundant forest resources in China, whose forest-cover rate and cumulation take the primacy of the whole country. Forest of Heilongjiang is an important part of the north forest of Eurasia (Editors Committee of Heilongjiang Forest 1993). However, as imperialist invaded in before liberation, forest was plundered and destroyed. After liberation, due to heavy cutting and slighting cultivation, maladjustment of cutting and cultivation, careless of management, disorder cutting and denudation and destroy forest to open up wasteland, which urged decrease of forest resources, constant descent of overlay rate, cumulation and

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quality of forest (Zhou *et al.* 1997). The paper analyzes the change of forest landscape pattern by modifying modified fractal and exponent of landscape diversity etc in Heilongjiang Province during different period, and revealing changing process of forest landscape. All patch types of forest landscape pattern were analyzed by using several indices of them.

Materials and Methods

Heilongjiang Province lies in the frontier of northeast of China (121°11'~ 135°5' E, 43°25'~ 53°33' N), bordering on Russia by Heilongjiang River in north and Wusuli River in the east respectively, near to Neimenggu municipality in the west, and Jilin Province in the south. The North belongs to frigid-temperate zone continent monsoon climate, and the South belongs to temperate zone continent monsoon climate. Annual even temperature is -4.9~4.2°C. ≥5°C accumulating temperate is 1 700-3 000°C. Annual even rainfall is 500-700mm, centralizing in June, July and August. Frostless is 80-150 days. Main soil types are temperate zone dark palm soil, frigid-temperate palm needle forest soil, gray forest soil and chernozem. Forest, grassland and farmland predominate in vegetation. There are hundreds of kinds of forest species, needle tree, include *Pinus koraiensis*, *Pinus sylvestris*, spruce-fir etc., broadleaf tree, including *Fraxnius mandshurica*, *Phellodendron amurense*, *Juglans mandshurica* etc. Heilongjiang is the largest forest region and the main base of food production (Editors Committee of Heilongjiang Forest 1993).

We take the maps of 1:2500000 forest resource distribution (1896, 1949 and 1981y), drawn by Forest Resource Investigation and Management Office of Heilongjiang Forest Chief Bureau, as the main data source. We used ARC/INFO to digitalize the maps, transform them to geography coordinate and take topology to generate vector data file (Li & Sun 2001). Meanwhile, we finished the coverage lap and other analysis by ARCVIEW. Using landscape indices analysis software package FRAGSTATS, based on ARC/INFO processing data, finally we obtain various landscape indices. FRAGSTATS can provide fifty eight different landscape indices, we chose six which had been used to analyze landscape changing (O'Neill *et al.* 1988; Li & Reynolds 1993; Gustafson & Parker 1992; Hamazaki 1992)

Total Area of total landscape is calculated by

$$TA=\frac{1}{10000}\sum a_{ij}$$

where *TA* is the area of total landscape(ha); a_{ij} is the area of patch *j* in the landscape of patch type (class) *i*(m^2).

Patch density is calculated by

$$PD=\frac{n_i}{A}\times 1.0\times 10^6$$

where *PD* is patch density (N/100ha), n_i is number of patches in the landscape of patch type (class), *A* is total area of patches type (class) *i* (hm^2).

Mean patch size is calculated by

$$MPS=\frac{1}{10000}\frac{\sum_{j=1}^{n} a_{ij}}{n_i}$$

where *MPS* is mean patch size (hm^2), a_{ij} is the area of patch *j* in the landscape of patch type (class) i (m^2), n_i is number of patches in the landscape of patch type (class).

Patch size coefficient of variation is calculated by

$$PSCV=\frac{PSSD}{MPS}(100)$$

where *PSCV* is patch size coefficient of variation, *PSSD* is patch size standard deviation (hm^2) and calculated by

$$PSSD=\sqrt{\frac{\sum_{j=1}^{n}\left[a_{ij}-\left(\frac{\sum_{j=1}^{n} a_{ij}}{n_i}\right)\right]^2}{n_i}}\left(\frac{1}{10000}\right)$$, *MPS* is mean patch size(hm^2).

Mean patch fractal dimension is calculated by

$$MPFD=\frac{\sum_{j=1}^{n}\left(\frac{2\ln p_{ij}}{\ln a_{ij}}\right)}{n_i}$$

where *MPFD* is mean patch fractal dimension, P_{ij} is the perimeter of patch *j* in the landscape of patch type (class) *i* (m), a_{ij} is the area of patch j in the landscape of patch type (class) *i* (m^2), n_i is number of patches in the landscape of patch type (class).

Mean shape index is calculated by

$$MSI=\frac{\sum_{1}^{n}\left(\frac{p_{ij}}{2\sqrt{\pi\cdot a_{ij}}}\right)}{n_i}$$

where *MSI* is mean shape index, a_{ij} is the area of patch j in the landscape of patch type (class) i (m^2), P_{ij} is the perimeter of patch *j* in the landscape of patch type (class) i (m), n_i is number of patches in the landscape of patch type (class) i.

Results and Discussion

The relationship between spatial pattern and ecology process is very important in ecology study (Wang *et al.*

1997). The analysis of landscape spatial pattern is an important and challenging problem. Spatial pattern can be discussed from two level, one is the relationship of patch pattern, which consist landscape and process, the other is the relationship of whole landscape pattern and process. The paper will discuss these two aspects.

Forest landscape pattern change in different time

In the table, NP is the number of patch, LPI is the largest patch index, IJI is the interspersion and juxtaposition index, SHDI is the Shannon's diversity index, SIDI is the Simpson's diversity index, SHEI is Shannon's Evenness index, SIEI is Simpson's Evenness index, TE is total edge in the landscape.

We can see from Table 1 and Fig.1 that the TA of forest decreases sharply, NP increases, PD increases, MPS decreases, IJI weaken, but MSI gradually regularizes, and MPFD simplifies. All of these have proved that forest landscape gradually fragmentate and the SHDI and SHKI of whole forest gradually decline.

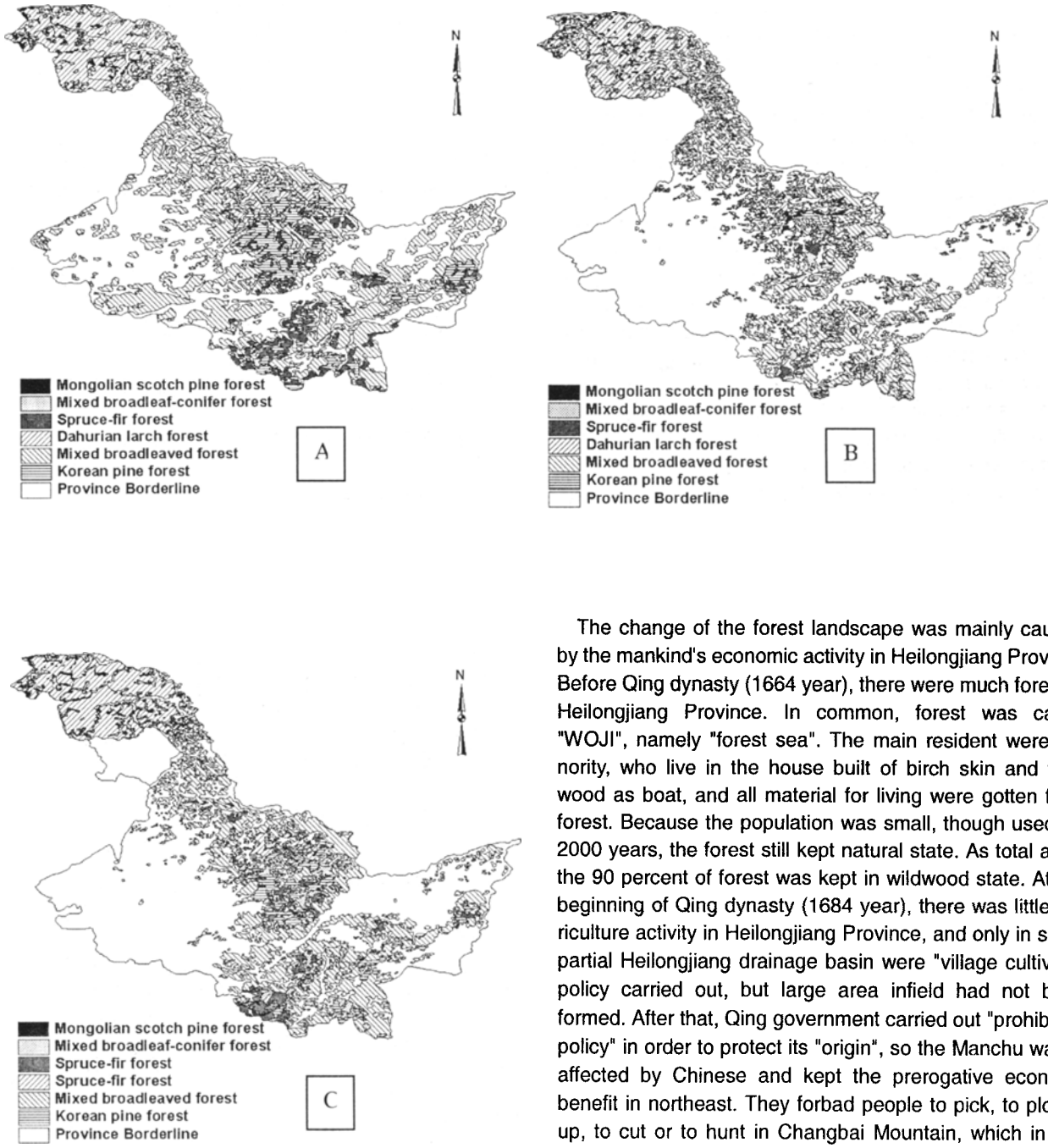

Fig. 1 Distribution of forest resource in Heilongjiang Province
A. 1896; B. 1949; C. 1981

The change of the forest landscape was mainly caused by the mankind's economic activity in Heilongjiang Province. Before Qing dynasty (1664 year), there were much forest in Heilongjiang Province. In common, forest was called "WOJI", namely "forest sea". The main resident were minority, who live in the house built of birch skin and take wood as boat, and all material for living were gotten from forest. Because the population was small, though used for 2000 years, the forest still kept natural state. As total area, the 90 percent of forest was kept in wildwood state. At the beginning of Qing dynasty (1684 year), there was little agriculture activity in Heilongjiang Province, and only in some partial Heilongjiang drainage basin were "village cultivate" policy carried out, but large area infield had not been formed. After that, Qing government carried out "prohibition policy" in order to protect its "origin", so the Manchu wasn't affected by Chinese and kept the prerogative economy benefit in northeast. They forbad people to pick, to plough up, to cut or to hunt in Changbai Mountain, which in fact protected a great amount of forest. In 1840 after Opium War, Qing government relieved "prohibition policy" in need of economy and military affairs. Because of chaos caused by

war in many years, many people from Hebei and Shandong Provinces swarmed into Heilongjiang Province constantly. They opened up wasteland, rebuilt houses and fell many trees, which caused destructing forest and the back off of forest edge. Marginal mountain was occupied by natural secondary forest predominated *Quercus mongolica*, because of picking, cutting and setting on fire constantly. Till 1896, Heilongjiang forest had been destroyed to some extends, and especially the forest near towns and along roads had been destroyed more seriously.

Table 1 Forest Landscape pattern indices in different year

Year	TA (10^7hm^2)	NP	LPI (%)	PD (N·100hm^2)	MPS (10^4ha)	IJI	MSI	MPFD	SHDI	SIDI	SHEI	SIEI	TE (m)
1896	3.0	1028	5.54	0.003	3.0	97.25	1.65	1.24	1.50	0.71	0.77	0.83	257.346
1949	2.3	914	5.08	0.004	2.5	95.92	1.64	1.23	1.58	0.73	0.82	0.86	206.379
1981	2.0	1256	5.27	0.006	1.6	94.99	1.47	1.21	1.39	0.67	0.72	0.78	175.233

Russia filched the right of building Middle East railroad in 1896, then they disafforest wantonly. From 1912 to 1931, the civil war continually broke out almost every year among warlords. Moreover imperialism plundered, and many forests were fell down with axe. During the war in which Japan invaded China (1931 year), Japan robbed a lot of resources, and large area of forest was destroyed. At the end of the war, forest was resumed to some extend in Heilongjiang Province. But many trees were cut in order to support liberation war, the area of Heilongjiang forest reduce consumedly till the eve of liberation (1949 year).

After liberation, Heilongjiang Province always took on producing commodity woods task in order to support national socialism construction. In some time, it reached 40 to 65 percent of the total task. Because of over 40 years' excessive cutting, adverse influence on our national economy building "left line", and severe impact from ten years' convulsion, producing and construction guideline, which was based on cultivating forest, wasn't completely carried out. The misplay of work in forest, without managing forest according to the law, scientific and economical rule, emphasizing to pick and neglecting to cultivate in long time, maladjustment between picking and cultivating, disjoining between cutting and recruitment, coarse management, cutting about and opening up wasteland (Table 2), all of which lead to the fact that the resource of forest decreased sharply, and covering rate, cumulation and quality of forest declined.

Table 2 Status of forest disappearing from 1976 to 1981 year in Heilongjiang Province (Editors Committee of Heilongjiang Forest, 1993)

Destroying Item	A	B	C	D	E	F	G	H	I	Total
Area (10^4hm^2)	18.8	10.8	6.2	13.9	19.8	1.24	0.62	4.67	3.9	79.9
Percent	23.65	12.88	7.77	17.53	24.98	1.58	0.78	5.87	4.96	100

Note: A is All cutting blanks, B is Cutting blanks, C is Farm, D is Foster, E is Disorder cutting, F is Deal in agaric and Breed silkworm, G is High voltage line, H is Fire, I is Railway and Road.

Another reason for the forest landscape pattern change in Heilongjiang is that climate change and forest community successes by itself in recent century. From the investigation of the seven seas, we can see that the change of the climate is most notable in the northern hemisphere high latitude area, so it is the main factor that influences the distribution of forest. The expending and moving of vegetation belt and the change of timberline have appeared several times in history in high latitude area that is usually caused by the change of temperature (Qi *et al.* 1999). The data of spore and fossil have proved that the broadleaf tree has grown in taiga 12000 years ago (Wu & Deng, 1996). The radicalization was much higher by 8 percent 8100-9200 years ago than today and the temperature was higher too. At that time, the location of timberline in tundra was apart from 100-200m distances to now. According to Tikhomiror's observation, the rise of temperature in recent 20 years has caused that the northern forest of Russia to move to the west. The tundra has begun to grow forest. Sometimes the speed of timberline moving to north is striking, Uspenski has observed that the speed can reach to several hundreds miles in one year in some region. High latitude region in Heilongjiang Province refer to main forest region in north part of 50° N –Daxing'an Mountain forest region, where Dahurian larch forest, Mongolian scotch pine forest and some north forest mainly distribute. The most important factor influencing the distribution of forest is the change of temperature. In middle latitude region (including part of north of Xiaoxing'an Mountains, southeast of Zhangguangcai Mountans and Wanda Mountain), the main factor affecting forest distribution is not the temperature but the change of precipitation. So the larger area, which was affected by climate for forest distribution in Heilongjiang, is in taiga and northern needle forest region (Liu & Li, 1999). The influence of temperature change on plants shows the change of function in short time (several year to decades). In long time, the influence is not location in function but also in composing and pattern (Zhang *et al.* 2000). Heilongjiang Province lie in East Asia and the climate compared with Europe and North America changed very little since the

Cretaceous period. Without remarkable and strong climate change, there was not vegetation subrogation phenomenon. Although the increase of greenhouse gas results in the phenomenon of temperature rising rapidly, it influences distribution range in some degree. The change of temperature does not overstep its limit, so it can't lead to the decrease or increase of forest area (Hong *et al.* 2002). Particularly compared with mankind's activity, the influence is negligible, but we cannot ignore the function of climate. If dioxide concentration increases at current rate and the government strengthen the measure of protection and management, climate will become a major factor which affects distribution pattern of forest landscape in Heilongjiang Province in a short period of time.

So we should comprehend the change of forest landscape in Heilongjiang Province, excessive cutting and strong mankind disturbance caused dramatic decrease of forest area (Fig. 2), and the change of climate aggravated this trend.

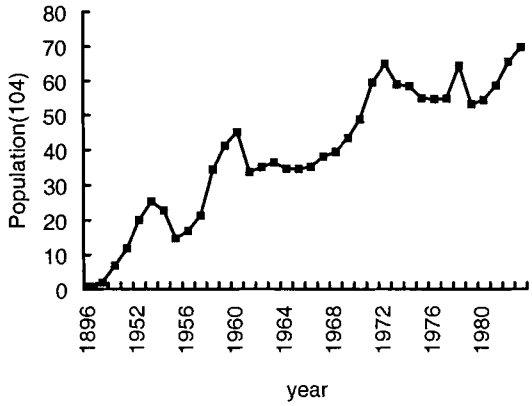

Fig. 2 Population of forest region in Heilongjiang Province form 1896 to 1983

The change of forest patch type in different time

From Fig. 3, we can see that the mixed broadleaved forest always dominate and the proportion of Mongolian scotch pine forest is the least, which indicate that mixed broadleaved forest is suitable for mountain or plain area in temperate or frigid temperate zone and it is a steady forest community kind. The adaptability of Mongolian scotch pine forest is poor, so there are not large area expect north part of Daxing'an Mountains, the other five kinds forest area is decreasing except mixed broadleaf-conifer forest, but the decreasing area of Korean pine forest is the most. Because Korean pine forest is a kind of high quality woody tree, everyone like using it, large area of original Korean pine forest was cut. Because of improper management, and the full growth time is so long, the change of Korean pine forest is the largest. Exception for mixed broadleaf-conifer forest, the patch density of other five patches increased more or less, among which Korean pine forest increased the most. This shows forest landscape in Heilongjiang Province has the trend of serious fragment, and Korean pine forest was destroyed the most seriously. The variation coefficient of the size of patches presented the increasing trend except Korean pine forest declining, among which that of Mongolian scotch pine forest changed larger, and spruce and fir and mixed broadleaved forest changed the smaller comparatively. Korean pine forest was destroyed the most seriously, which is concluded from the changes of variation coefficient and distributing areas. The variation coefficient of other types increased because the reducing in areas. The increasing trend of evens fractal of the other five patches except Dahurian larch forest showed that the edge of patches was more complicated than before. The shape of Dahurian larch forest patch had a trend of regularization and simplification. The even size of patches declined except Mongolian scotch pine forest and mixed broadleaf-conifer forest, but changing the most seriously was Korean pine forest and broad leaves. These results showed declination in areas and the trend of fragment in whole forestry landscapes, especially in Korean pine forest. The regularization and shape index of patches changed little, however, every types of landscape had the trend of fragment and declination in areas.

The areas of the whole forest landscape decreased because part of forest had been transformed to other landscape types such as farmland, grassland and urban, and part of it degenerated as second forest which has no preponderant tree species and low value in use. Some of the forests retrogress as desert. The transformation among different patch types were low, Korean pine forest transformed to mixed broadleaf-conifer forest were higher, spruce-fir forest transformed to Dahurian larch forest were higher too.

Conclusion

As a result, the total area of forest landscape and mean patch size decreased sharply, the quantity and density of patches increased, the juxtaposition of patches weakened, the shape of patch tended to become regular, and the border of patch simplified. All these showed that forest landscape tended to fragment gradually, and the fragment of Korean pine forest is the severest. The diversity of whole forest landscape and the evenness of landscape types distribution reduced gradually. These changes were caused by mankind's economic activity, climate change and forest community succession in recent centuries. But compared with mankind's disturbance, the latter effect was faint.

We should hold the protection and management as an important work. Implementing natural forest protection has very important meaning to promote rehabilitation of forest department, to breed and to protect forest resource, to protect biodiversity and to improve environment. Protecting current forest resource, combination between picking and raising, implementing natural forest protection and making a way of sustainable development in forest management is

the only and the best way to solve all of those problems.

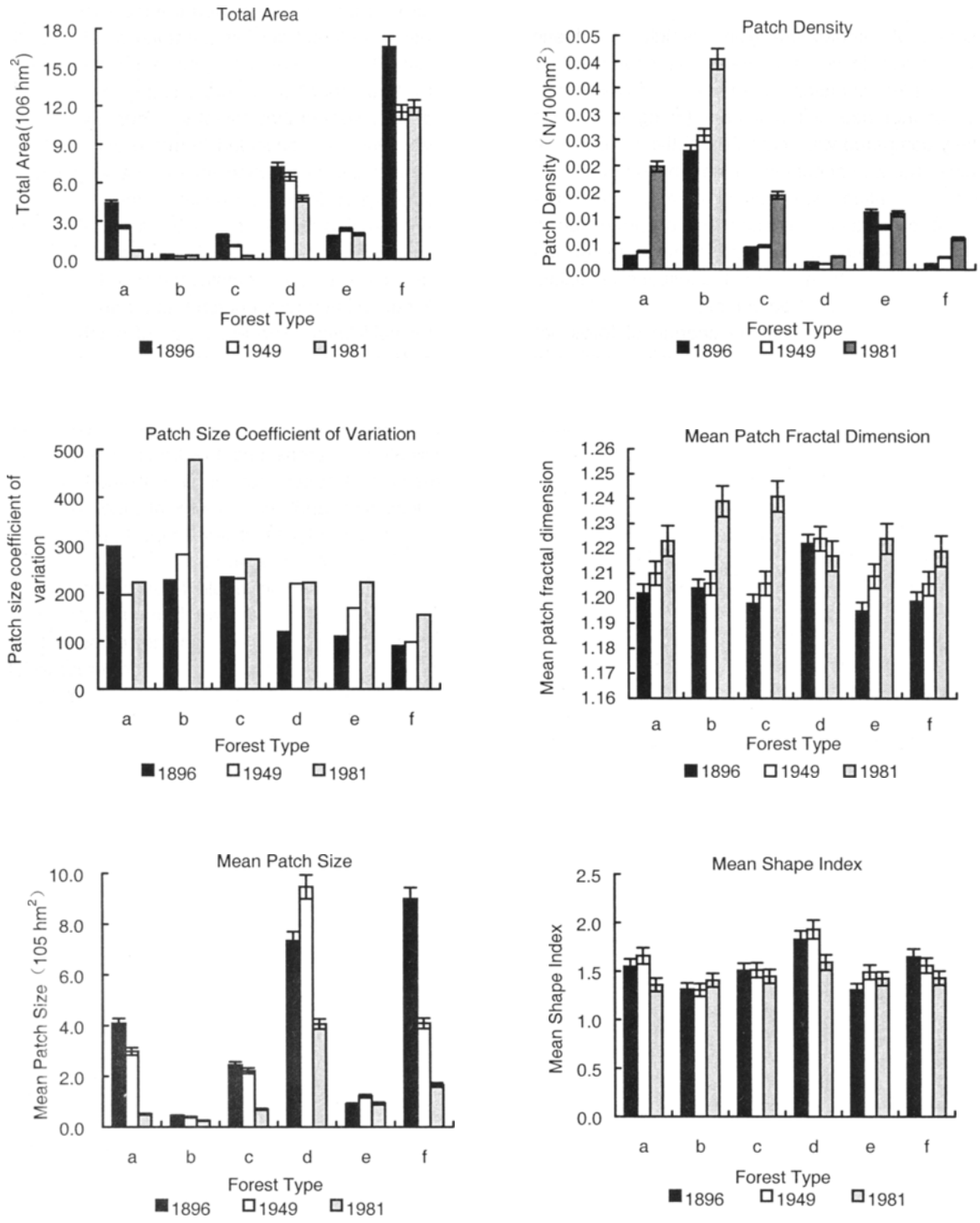

Fig. 3 Pattern change of different patch type in different year

In the figure, a is Korean pine forest, b is Mongolian scotch pine forest, c is Spruce-fir forest, d is Dahurian larch forest, e is Mixed broad-leaf-conifer forest, f is Mixed broadleaved forest.

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